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Coded-Wire Tagging of Wild
Sockeye Salmon Smolts
at Hugh Smith Lake, Alaska

by
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ABSTRACT

Sockeye smolts emigrating from Hugh Smith Lake were tagged with coded-wire tags during 1980 through 1982. Unacceptable short-term mortalities (5.1% to 9.1%) encountered during the initial year of tagging were reduced to acceptable levels (<3.0%) in subsequent years. Monitoring adult returns from the initially tagged smolts (1980) began in 1982 and continued through 1985. In 1984 there were 545 accountable tag recoveries from adults captured in the commercial fishery and at the Hugh Smith counting weir. Using accountable tag recoveries in 1984, the U. S. commercial fisheries exploitation rate was estimated at 62.8%.

Based upon yearly differences between the ratio of tagged and untagged smolts leaving the lake the ratio of tagged and untagged adults returning, we observed smolt-to-adult tagging mortalities of 87.6% and 91.3%. Correcting for this mortality resulted in changes in our estimates of ocean survival rates of 1981 Hugh Smith smolts from 1.7% to 13.7%. Despite the apparently high tagging mortalities of wild sockeye smolts, the overall results encourage the further development of coded-wire-tags as a management tool.

KEY WORDS: sockeye salmon, *Oncorhynchus nerka*, smolts, marine survival, exploitation rates, coded-wire

INTRODUCTION

Use of a unique coded-wire-tag (CWT) to identify individual fish stocks has become a common practice since its development by Jefferts et al. (1963). In the Pacific Northwest most agencies involved in the culture of anadromous salmonids currently use CWTs to determine commercial harvest rates of returning hatchery stocks. Coded-wire tagging is also used to determine the effects of various rearing treatments (e.g., food types, feeding rates, release dates) on adult return rates (Holland 1983). However, coded-wire tagging has been used only to a limited extent on wild salmonid stocks; e.g., coho salmon, *Oncorhynchus kisutch*, to identify migration patterns and harvest rates (Shaul et al. 1983, 1984, and 1985).

In 1979 the Alaska Department of Fish and Game (ADF&G), Division of Fisheries Rehabilitation, Enhancement, and Development (FRED), began a lake fertilization research project at Hugh Smith Lake; its main goal was to increase sockeye salmon, *Oncorhynchus nerka*, production by increasing the amount of limnetic forage available to lake-rearing fry. A major segment of the evaluation involved the determination of smolt-to-adult survival rates. As adult sockeye returning to Hugh Smith Lake had to pass through an intensive gill-net and seine fishery in both the United States and Canada, a CWT program was initiated in 1980 to determine the harvest rates.

The inlake capture of large numbers of sockeye fry for coded-wire tagging purposes is impractical because they are widely dispersed throughout the lake; accordingly, wild sockeye smolts were tagged leaving Hugh Smith Lake. In hatchery situations, most CWTs are applied to salmonid juveniles prior to smolting (Johnson 1984) because they become extremely delicate during smoltification (Wedemeyer et al. 1980). Handling, drug treatments, and scale loss (singularly or in combination) can stress the smolts. Stress that requires severe metabolic adjustments, especially at this critical life stage, will be lethal, while less severe stress may lead to physiological disorders or an increased incidence of infections (Wedemeyer 1970).

This paper describes the Hugh Smith Lake sockeye smolt coded-wire tagging operation from 1980 to 1982 and discusses both the problems encountered and results received.

Study Site Description

Hugh Smith Lake (50° 06'N, 130° 40'W) is located in mainland Southeast Alaska, ~80 km southeast of the city of Ketchikan (Figure 1). It has a surface area of 309 ha and is surrounded by a mountainous watershed (49.47 km^2) that receives 381 cm of precipitation annually. Sockeye Creek (ADF&G stream identification code 101-30-75), is the outlet stream that drains into Boca de Quadra; it is approximately 50 m long (from the lake to mean high tide), with an elevation drop of only 4 m. The creek is 25 m wide at the lake outlet, and its discharges range from 1.4 to 28.3 m^3/sec. The water level at the lake outlet fluctuates over a 2-m range, and peak flows occur in late fall.

METHODS AND MATERIALS

Sockeye Smolt Capture

On 17-19 May 1980, sockeye smolts were captured in Sockeye Creek, using a 1.0- x 0.5-m x 0.6-cm mesh fyke net that had 3-m wings and a 1.0- x 0.5- x 0.5-m live box attached to the cod end. The net was placed in mid-channel at the lake outlet and supported by 1.2-cm-diameter pipes driven into the streambed. This gear captured large numbers of fish but caused excessive

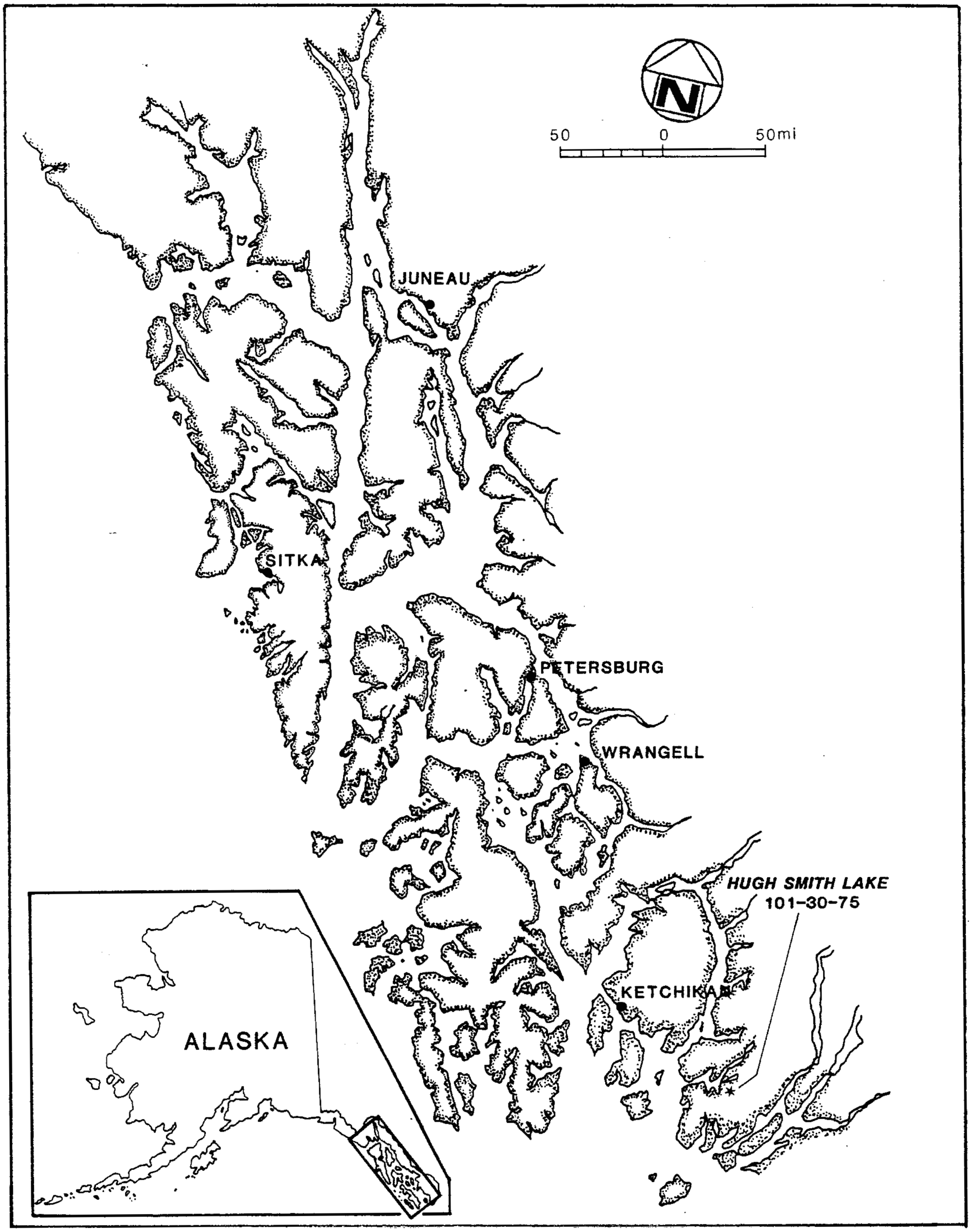

Figure 1. Geographic location of Hugh Smith Lake in Southeast Alaska relative to the city of Ketchikan.

mortalities, and the descaling of fish resulted in stressed fish of poor quality for CWT implantation. Consequently, on 1-3 June 1980, the weir for counting adults in Sockeye Creek was covered with 0.6-cm mesh plastic netting, except for three 0.5-m openings. Three 1.0- x 0.5-m x 0.6-cm mesh fyke nets with 1.0- x 0.5- x 0.5-m live boxes on the cod ends were placed in the front of the openings in the weir. All smolts passing through these openings were captured by the fyke nets and held in the live boxes until processed.

Sockeye smolts receiving a CWT in 1981 and 1982 were obtained through the use of a smolt weir which was located above the lake outlet in an area having little or no current. The smolt weir consisted of 6.1-m-long wooden panels that were covered with 0.6-cm mesh plastic netting. The panels were 1.2- to 2.4-m deep. Panel depths closely matched the bottom contour at the lake outlet; however, gaps between the bottom of the smolt weir and the outlet bottom were blocked with a 0.6-cm mesh hardware cloth. The areas between both ends of the smolt weir and the shore were blocked using plastic netting attached to iron pipes driven into the lake bottom. A funnel shaped opening, measuring 1.7 x 0.7 m at the mouth and 6 x 6 cm at the end and leading to a 1- x 1- x 1.2-m holding box, was located between two of the weir panels. A platform led from the holding box to a tagging shed containing the CWT equipment.

Smolt Tagging, Recovery, and Short-Term Mortality

The CWT machine and tagging process has been given intensive discussion by Koerner (1977), Moberly et al. (1977), and Jenkinson and Bilton (1981). Solutions containing 80-135 mg/l of MS-222 were used to anesthetize smolts prior to tagging. In 1980 sockeye smolts were taken from the fyke-net live boxes and placed in 19-liter plastic buckets for transport to the tagging station; they were immediately anesthetized, their adipose fins were clipped, and they were tagged with full length CWTs and placed into a bucket for recovery. After a group of fish were tagged, they were moved to a 1- x 1- x 1.5-m holding box in Sockeye Creek and held for 3 hours prior to release. All mortalities were collected and checked for tag retention. The percentage of valid tags for all released smolts was based on the tag retention rate of the dead fish.

In 1981 and 1982, sockeye smolts receiving CWTs were dipped from the holding box in groups of 30-50 fish and put in a fin-clipping tray containing a solution of MS-222 (80-135 mg/L). In the tagging shed, the smolt's adipose fins were clipped; they were tagged with full length CWTs, passed through a magnet, checked for tag retention with a field-sampling detector (fish without tags were retagged), and placed in an aerated recovery bucket: this process is referred to as the Quality Control Procedure (QCP). After recovery from the anesthetic, the fish were released into a quiet pool below the weir from which they could volitionally migrate downstream. Processing time for each batch of fish was generally less than 5 minutes. Because of the QCP, tag retention at release was 100%. Finally, in 1982 three subsamples of coded-wire tagged smolts were placed in holding pens for 24 to 48 hours in order to determine short-term tagging mortality.

<u>Recovery of Tagged Adults</u>

Adults returning to the Hugh Smith weir from 1982 to 1984 were checked for adipose finclips. Those having clipped fins were killed, their heads removed, and the heads then sent to the ADF&G, FRED Division, Tag Recovery Lab for tag removal and analysis. Adults captured in the commercial fishery were recovered on a random basis by ADF&G, Commercial Fisheries Division, Tag Recovery Program. Adults recovered in the commercial fishery were also processed by the FRED Tag Recovery Lab.

RESULTS

Short-Term Mortality of Tagged Smolts

The netting method used to capture fish in 1980 resulted in poor-quality fish for CWT implantation because the fish had been stressed and had experienced varying degrees of scale loss. The number of post-tagging mortalities in 1980 ranged from 5.1% to 9.1%; this indicated the poor condition of the fish (Table 1). As the CWT-smolts released were in fair to poor condition, we did not expect that the tagged fish would be comparable to untagged Hugh Smith smolts in respect to marine survival. In addition, as 1980 was our first year of work at Hugh Smith, the size of smolts was unknown. Consequently, the head mold for the tagging machine was too large, and this resulted in low tag retention, ranging from 82.5% to 85.8%.

In contrast, fish captured with the smolt weir in 1981 and 1982 were of good quality for CWT implantation, as the majority of the smolts were removed from the holding box as soon as they entered. This helped alleviate stress, and scale loss did not appear to be excessive. These observations were confirmed in 1982 by the short-term tagging-mortality study, which indicated little mortality for up to 48 hours after tagging (Table 2). These three separate studies, conducted when smolts were emigrating from the lake, showed short-term mortalities ranging from 1.7% to 3.0%. As a result, CWT-smolts released in 1981 and 1982 were considered to be in good shape; and their marine survival was not expected to be adversely affected by the CWT implants.

Recovery of Coded-Wire Tagged/Finclipped Adults

The first recovery of CWT-adults occurred in the 1982 when seven sockeye from the 1980 tag lot returned to the adult weir

Table 1. Number of sockeye smolts receiving a coded-wire tag (CWT) at Hugh Smith Lake during 1980-1982.

Smolt year	Dates	Tag code	Smolts tagged (No.)	Immediate tagging mortalities (No.)	Tag retention at release (%)	Validly tagged smolt released
1980	5/17-19	4-19-06	1,237	113	85.8	964
1980	5/31-6/04	4-19-06	3,912	200	82.5	3,062
1981	5/13-19	4-20-46	10,546	18	100.0[a]	10,528
1981	5/19-27	4-20-47	10,227	2	100.0[a]	10,225
1981	5/27-6/10	4-19-25	7,621	0	100.0[a]	7,621
1982	5/17-6/09	4-21-61	30,000	0	100.0[a]	30,000

[a]Estimated through the use of Quality Control Procedure (QCP)

Table 2. Short-term mortality studies of sockeye smolts with a CWT at Hugh Smith Lake in 1982.

Date	Smolts held (No.)	Retention time (hours)	Mortalities	
			Number	Percent
5/18/82	104	24	2	1.9
5/24/82	100	48	3	3.0
6/01/82	120	48	2	1.7

(Table 3). Adult sockeyes from the 1980 and 1981 tagged smolts returned in 1983, and adult fish from all three tag years were recovered in 1984. In 1984 U. S. commercial recoveries accounted for 62.8% of the 545 accountable tag recoveries, while the remainder were found at the weir site. CWTs from the 1980 tag lot were recovered from fish that had spent 2, 3, and 4 years in salt water.

The percentage of CWTs in adult sockeye returning to Hugh Smith Lake from the 1980 and 1981 tag lots was nearly identical for the 2-ocean and 3-ocean return years (Table 4).

Smolt-to-adult survival rates for the 1980 and 1981 tag lots ranged from 0.5% to 2.3% (Table 5). In 1981 three lots of sockeye smolts received CWTs. The first two lots tagged had comparable smolt-to-adult survival rates of 2.3% and 2.0%, while the survival rate of the third lot was four times lower (0.5%).

Differential Mortality Between Tagged and Nontagged Smolts

We compared the percentages of the tagged smolts in the outmigration to the percentages of corresponding tagged adults at the weir and found vastly different ratios (Table 6). In 1981 an estimated 8.9% of the smolts released had a valid tag, compared to only 1.1% of the returning adults. Similarly, in 1982 even though we tagged a considerably higher percentage of the smolts (33.2%), only 2.9% of the returning adults had tags. The two percentages should be equivalent, unless one or more of the following occurred: (1) poor tag retention and/or a large amount of fin regeneration; (2) a miscalculation of smolt numbers; or (3) significant mortality attributable to tagging.

First, we determined that tag retention rates of the 1980 tag lot were poor (<50%), but this was expected because of the

Table 3. Summary of Hugh Smith Lake CWT-adult sockeye salmon returning to the weir and caught in the U. S. commercial fishery.

	Returns by tag code[a]										
	4-19-06		4-20-46		4-20-47		4-19-25		4-21-61		
Year	Lake	Catch[b]	Lake	Catch[b]	Lake	Catch[b]	Lake	Catch[b]	Lake	Catch[b]	Total
1982	7										7
1983	20	17	7	2	12		2				60
1984		7	78	154	64	124	16	19	45	38	545
Total	27	24	85	156	76	124	18	19	45	38	612
Grand Total	51		241		200		37		83		612

[a]Commercial returns include expansions for sampling design and lost tags

[b]Commercial fishery recoveries

Table 4. Percentage of returning Hugh Smith Lake adult sockeye with a CWT from the 1980-1982 smolt tag lots.

Smolt year	Return-year	Adults at weir (No.)	Adults with a CWT (No.)	Percent tagged
1980	1982 (2-ocean)	2,250	7	0.3
	1983 (3-ocean)	8,236	20	0.2
1981	1983 (2-ocean)	1,911	21	1.1
	1984 (3-ocean)	14,605	158	1.1
1982	1984 (2-ocean)	1,576	45	2.9

Table 5. Smolt-to-adult survival of Hugh Smith Lake sockeye salmon with a CWT.

Tag code	Smolt year	Tagged smolts released	Tagged adults in return	Marine survival rate (%)
4-19-06	1980	4,026	51	1.3
4-20-46	1981	10,528	241	2.3
4-20-47	1981	10,225	220	2.0
4-19-25	1981	7,621	37	0.5

Table 6. Apparent tagging-induced mortality rates of sockeye smolts following CWT implantation as determined by comparison of the ratio of tagged to untagged smolts versus the ratio of tagged to untagged returning adults.

Smolt year	Percent of smolts with tags	Percent of adults with tags	Apparent[a] tagging induced mortality
1981	8.9	1.1	87.6
1982	33.2	2.9	91.3

[a]Part of this is due to some fish not retaining their tags

Table 7. CWT retention rates for returning Hugh Smith Lake adults from smolts tagged during 1980 to 1982.

	2-ocean adults			3-ocean adults		
Smolt year	Number missing adipose fins	Number with CWT	Tag retention (percent)	Number missing adipose fins	Number with CWT	Tag retention (percent)
1980	7	3	42.9	41	20	48.8
1981	40	21	52.5	100	92	92.0
1982	34	33	97.1			

logistical problems encountered in the initial year of tagging (Table 7). In addition, the retention rate from one 1981 tag lot was poor (52.5%) for the 2-ocean component, but it was excellent (92%) for the 3-ocean adults. Since the 3-ocean returns were dominate (84%), we considered the overall tag retention rate to be excellent; the retention rate (97%) for the 1982 tag lot was also excellent. Thus we feel that tag retention was not responsible for the differences in CWT ratios between adults and smolts.

If fin regeneration was a problem a wide array of abnormal looking adipose fins would be expected on returning adults. As abnormal adipose fins were not observed, we believe fin regeneration did not compromise our results.

Second, sockeye smolts were obtained through the use of a smolt weir in both 1981 and 1982. In 1980 an estimate of the number of outmigrating smolts was obtained through subsampling. We feel that this estimate is reliable, although it could be lower than the actual number. In 1982 a total count of the outmigrating sockeye smolts was made, but some could have conceivably left the lake before installation and/or after removal of the smolt weir. Therefore, the outmigration estimates for 1981 and 1982 should be considered as conservative ones, and those for the percentage of smolts tagged as an upper limit. However, underestimating the smolt outmigration by 25% would reduce the percentage tagged from 8.9% to 6.7% and from 33.2% to 24.9% in 1981 and 1982, respectively (Table 6). In this example, the percentage of outmigrating smolts tagged for both years is still vastly different from the percentage of tagged returning adults. Thus a miscalculation of the smolt outmigration may account for some, but not a significant portion of the difference.

Third, we consider a likely contributing factor to the poor return of CWT-adults to be the differential mortality between tagged and untagged smolts occurring after tagging and release. The differences between the percentage of tagged smolts in the outmigration and those returning as adults suggest 87.6% and 91.3% tagging mortalities for smolts tagged in 1981 and 1982, respectively (Table 7).

DISCUSSION

The CWT adult return data from the 1980 tagged smolts was incomplete as problems encountered in this initial year of tagging undoubtedly resulted in poor survivals. Thus the number of tagged adults returning was probably so small that they were not adequately sampled in the commercial fishery. However, the CWT return data from the 1981 and 1982 tag lots enabled us to provide consistent estimates of the commercial harvest rates. These harvest rates could have been grossly underestimated had we not sampled for CWTs in adults returning to the lake. Many CWT programs use the percentage of smolts that were tagged at release to expand the catch statistics. If we had relied on this conventional methodology, our estimate of the commercial harvest of the 1981 tag lot would have been underestimated by eightfold. The existing data indicate a minimal U. S. harvest of 62.8% of the returning adult sockeye to Hugh Smith Lake in 1984. No sockeye CWT recovery program exists in adjacent Canadian waters, but the harvest is believed to be significant (Hoffman 1985). Hence, any enhancement activities directed at Hugh Smith Lake sockeye will benefit the fisheries in both the United States and Canada.

The high mortalities (i.e., 87.6% to 91.3%) suffered by sockeye smolts receiving CWTs are of concern, as most fish tagged in a hatchery environment exhibit survivals similar to nontagged fish (Johnson 1984). As most hatchery tagging is performed on fingerlings rather than smolts, we feel that a crucial difference in results lies in the life stage of the fish at the time of tagging. This difference is significant because all handling produces varying degrees of stress in juvenile fish (Wedemeyer 1972); stress, in turn, affects many physiological activities, including osmoregulation (Mazeaud et al. 1977; Wedemeyer et al. 1980). Redding and Schreck (1983) suggest that stressed coho salmon experience osmoregulatory problems that are exacerbated by their transfer from fresh water to salt water; thus an improperly functioning osmoregulatory system caused by tagging-related stress during transition from freshwater to saltwater could be lethal (Wedemeyer et al. 1980).

Anesthetics are commonly used to immobilize fish during handling and are an obvious necessity in CWT implantation. For tagging purposes, the most widely used anesthetic in Alaska is MS-222 (Moberly et al. 1977). Bouck and Johnson (1979) found that coho salmon smolts experience total mortality when anesthetized with high (100 mg/L) concentrations of MS-222 and transferred directly into sea-water. Strange and Schreck (1978) reported similar results for yearling spring chinook salmon, *Oncorhynchus tshawytscha*. Conversely, both Bouck and Johnson (1979) and Strange and Schreck (1978) reported little or no mortality when moderate to low concentrations (<75 mg/L) of MS-222 were used before their direct transfer to seawater. The concentrations (80-135 mg/L) of MS-222 used for tagging purposes at Hugh Smith Lake were in the high range, but exposure times were less than those used in the previously cited studies. In addition, the fish were released into fresh water instead of directly into salt water; the amount of recovery time they spend in fresh water before moving downstream into salt water (a distance of 50 m) is not known, but sockeye smolts receiving CWTs were often observed in Sockeye Creek several hours after tagging had ceased.

Another potential problem is scale loss; e.g., as sockeye smolts readily lose scales with even minimal handling. Bouck and Smith (1979) report that as little as a 10% scale loss on coho smolts can induce heavy mortality if the fish are placed immediately in seawater. We attempted to lessen the mortality by not tagging smolts with evident scale loss. There were undoubtedly some fish tagged that had varying degrees of scale loss, but we believe losses attributable to this were minimal and could not account for the magnitude of the losses incurred.

The actual source of the differential survival between tagged and nontagged sockeye smolts from the 1981 and 1982 tag lots remains elusive; however, Wedemeyer (1972) suggests that handling stress is not always apparent, and unless immediate death occurs, the severity of stress experienced by smolts and the time they need to recover are not evident. Since the smolts receiving CWTs appeared healthy upon recovery from the anesthetic, the cause of the mortality may have been a delayed reaction occurring sometime after release. We feel that a combination of handling stress, scale loss, and shortened recovery time from the anesthetic reduces the osmoregulatory capacity of the sockeye smolts. Given the short distance from the lake to salt water (50 m), an osmoregulatory problem could readily account for high smolt mortalities (Wedemeyer 1970, Wedemeyer et al. 1980).

Finally, differences in coded-wire tagged:untagged ratios between smolts and adults have been observed in other studies. For example, according to Bergman (1968) survivals of coded-wire tagged wild coho smolts were lower than untreated fish; and Thedinga and Koski (1984) found that by using the marked/unmarked ratio of returning adults, estimates of smolt production were over twice the actual number of smolts captured. Considering that in two different years 35% and 28% of the coho smolts were sampled for scales, anesthetized, coded-wire tagged, finclipped (adipose), and treated with malachite green; Thedinga and Koski (1984) agreed with the hypothesis that smolts captured at the weir have a lowered ocean survival than those not handled.

Recommendations

1. Future coded-wire tagging of wild sockeye salmon smolts should include procedures to determine the differential mortality occurring between tagged and untagged fish.

2. Sockeye smolts receiving a CWT should be held for varying periods of time to determine short-term mortality rates. If the distance from the point of tagging to salt water is short (<400 m), tagged smolts should be held in saltwater pens so that the effects of tagging on subsequent osmoregulatory capabilities can be tested.

3. Additional attention should be directed toward minimizing the short-term effects of anethetics on juveniles after tagging. Alternatives to MS-222 (e.g., 2-phenoxyethenol) should be tested.

4. Experimental groups of smolts should be tagged with different tag codes to determine any differential mortality after release.

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